Name: ____ Date: ____________________

A Sunny Day Gives Me a Charge

or

Renewable Energy Dude (RED) Starts "The Human Heliostat Competition"

SAFE -Safety Always First Everywhere

For this lab we will be using small solar panels (AKA photovoltaic cells) intended to slowly charge 12 volt automotive batteries. These are low voltage devices that offer little hazard of shock. They do need to be handled carefully. While some hazardous materials are used in the manufacture of solar cells, there are no direct hazards in handling them in this lab/activity. Please click on the link below and read about the handling, storage, and disposal of photovoltaic cells.

http://www.nrel.gov/docs/fy99osti/24618.pdf

MSDS

For most solar panels, silicon is the key ingredient. The MSDS (Material Safety Data Sheet) is an easily obtained document that describes the risks associated with materials as well as practices for safe handling, transport, storage, and disposal. Here is a link for the silicon MSDS:

http://www.sciencelab.com/msds.php?msdsId=9924921

Content Objective

Students will be able to describe the basic design and function of a photovoltaic cell through drawing and written or spoken explanation. Students will be able to estimate the efficiency of the photovoltaic cell while demonstrating an understanding of the importance of orientation and alignment with the sun.

Word Wall Terms & Concepts

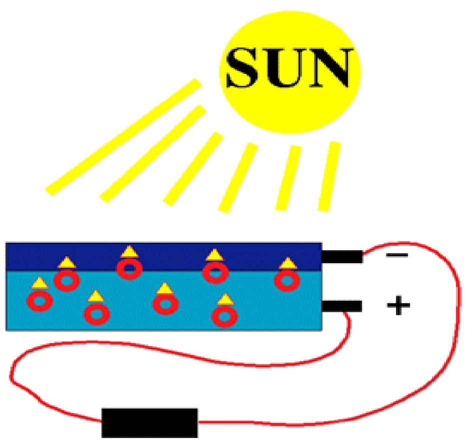
Light energy	Heat energy	Electrical energy	Watts
Kilowatts	Volts	Amps	Silicon
Multimeter	Photovoltaic cell (PV)	Latitude	GPS
Declination	Solar energy	Renewable energy	Efficiency
milli-	micro-	DC (Direct Current)	Rectifier
Transformer	Inverter	AC (Alternating Current)	Polarity
Ground	GFCI (Ground Fault Circuit Interrupter)		Fuse
Battery	Azimuth	Wire	Connector

Introduction

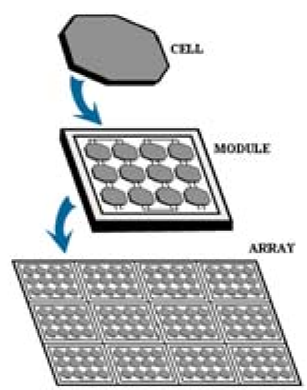
The sun produces 3.9×10^{26} watts of energy every second. Of that amount, 1,386 watts fall on a square meter of Earth's atmosphere and even less reaches Earth's surface. ***This energy can be used to generate electricity without producing pollution or dangerous wastes.*** Photovoltaic (PV) cells convert sunlight directly into electricity and are used to run small appliances such as calculators and outdoor light fixtures. Many PV cells can be wired together to form panels that can be used to run larger devices such as irrigation pumps, radar stations, and even refrigerators. How much power does a PV cell produce? How efficient is a PV cell at converting the sun's energy into power?

Source:
http://www.cpo.com/home/Portals/2/Media/post_sale_content/PES/PES_Chap_27/StudentRecordSheets/PES_INV_AS_27C.pdf

Introduction continued: Solar Cells or Photovoltaic Cells



We can also change the sunlight directly to electricity using solar cells. Solar cells are also called photovoltaic cells – or PV cells for short – and can be found on many small appliances, like calculators, and even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made of silicon, a special type of melted sand.



When sunlight strikes the solar cell, electrons (red circles) are knocked loose. They move toward the treated front surface (dark blue color). An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, like a wire, a current of electricity occurs between the negative and positive sides.

These individual solar cells are arranged together in a PV module and the modules are grouped together in an array. Some of the arrays are set on special tracking devices to follow sunlight all day long.

The electrical energy from solar cells can then be used directly. It can be used in a home for lights and appliances. It can be used in a business. Solar energy can be stored in batteries to light a roadside billboard at night. Or the energy can be stored in a battery for an emergency roadside cellular telephone when no telephone wires are around. Some experimental cars also use PV cells. They convert sunlight directly into energy to power electric motors on the car.

Photo credit: NASA

But when [many] of us think of solar energy, we think of satellites in outer space. Here's a picture of solar panels extending out from a satellite.

Source: [www.**energy**quest.ca.gov/story/chapter15.html](www.energyquest.ca.gov/story/chapter15.html)

The Human Heliostat Competition

Today, your group is going to calculate the efficiency of a photovoltaic cell. As a team, you are going to explore the factors that may affect the efficiency of the PV cell. Your team will need:

1. A PV cell (THUNDERBOLT MAGNUM 1.5 WATT solar battery charger purchased at Harbor Freight Tools)
2. A digital multimeter (CENTECH Digital Multimeter purchased at Harbor Freight Tools)
3. A protractor
4. A clock (set accurately-smart phones can do the job)
5. A ruler with centimeter divisions.
6. A compass for orientation (camping department at WalMart, also available as a smartphone app).
7. A one square meter cardboard square with marked compass directions
8. A large, dark Sharpie for marking the cardboard
9. Lab journal for recording data.

Team Members and Roles:

1. Chief--Organizes materials, keeps team on task following procedure, timekeeper.
2. Human Heliostat--Holds PV cell, moves and aims PV cell at sun.
3. Angles Measurer--Marks compass direction and azimuth reading in degrees every 2 minutes.
4. Multimeter Person--Gets Voltage and Amperage readings every 2 minutes.
5. Progress Recorder--Assembles data from the team and records it in the table below.

Procedure:

1. Each CHAMP team needs to find an unshaded location for their observations.

2. Use the compass to locate magnetic north, for this activity, all teams will orient their cardboard square with magnetic north (no need to worry about declination yet).

3. Have the Human Heliostat stand on the center of the cardboard, holding the PV cell directly in front of him/herself at an angle directed at the sun.

4. The Angles Measurer will mark the starting position and measure the tilt of the PV cell in degrees, this information will be reported to the progress recorder.

5. The Chief will observe the start time and report it to the Progress Recorder.

6. The Multimeter Person will get a voltage and amperage measurement and report these to the Progress Recorder.

7. Every 2 minutes, the Human Heliostat will reorient him/herself to align the PV cell with the sun and steps 1-6 will be repeated.

Note: Record your observations (Time through Amps) in the table below but PLEASE read all instructions before doing the calculations and entering them in the table.

Time	Dir. ^{0}	"Tilt"^{0}	Volts	Amps	Watts/M^2 (VxA)	Possible Watts Estimate	Efficiency

How efficient is your photovoltaic cell?

In this part of the investigation, you will determine how much of the energy that is reaching your PV cell is being converted into power. To do this, you will use your data that you entered in the table above.

a. Use the formula below to calculate the power output of your PV cell in $watts/cm^2$.

$$\frac{\text{voltage x amps (current)}}{\text{area of PV cell}} = watts/cm^2$$

b. Multiply your result by 10,000 to convert the value to $watts/m^2$.

Record this result in the table above.

The amount of the sun's energy that reaches the edge of Earth's atmosphere is known as the solar constant. While the solar constant varies slightly, the average value is 1,368 watts per square meter (W/m^2). To visualize this amount of energy, imagine the energy of thirteen 100-watt light bulbs spread over a single square-meter surface.How much of this energy actually reaches Earth's surface on a sunny day? This amount varies according to the time of year. The following values are estimates for how much energy reaches Earth's surface on a sunny day, according to the time of year:

- *1000 $watts/m^2$ on a sunny summer day.*
- *900 $watts/m^2$ on a sunny autumn or spring day.*
- *700 $watts/m^2$ on a sunny winter day.*

Depending on the time of year, one of the values above is the power input from the sun that is converted into electrical energy by your PV cell.

c. Calculate the efficiency of your photovoltaic cell using the formula below.

% efficiency = [(power output of PV cell in $watts/m^2$)/(power input from the sun in $watts/m^2$)] x 100

Record your result in the table above.

d. Most PV cells have efficiencies between 5 and 20 percent. How does yours compare?

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Applying your knowledge

a. Besides angle, what other factors do you think will affect the energy output of your PV cell?

Source:
http://www.cpo.com/home/Portals/2/Media/post_sale_content/PES/PES_Chap_27/StudentRecordSheets/PES_INV_AS_27C.pdf

CHAMP Teams Data Collection and Comparison--Determining the Winner!!

Circulate and collect data from all the other teams and plot it on the graph below. Be sure to label the axes, title the graph, plot ALL points correctly, and identify the lines for the various teams. As you collect data and discuss findings with other teams, record any thoughts, observations, or questions here.

TITLE:

X-AXIS :

Y-AXIS:

CHAMP GROUP SYMBOL OR COLOR: ______________________________________

Once you have finished, have the CHAMP team Chiefs work together to review the graphs and declare the winner of the Human Heliostat Competition.

Scientific Method Connection:
"The Human Heliostat Competition"

Investigative Question:

Hypothesis:

Experimental Design:

Equipment:

Materials:

Procedure (List Steps):

Results (see table) write brief summary of findings:

Analysis (see graph) write brief description of what the graph shows:

Conclusion-connect findings with your hypothesis and write a CER (Claim, Evidence, Reasoning) summary :

Reflection:
What did you learn from this lab/activity?

What could you have done to improve your learning and/or the outcome of this lab/activity?

What could your team members have done to improve your learning and/or the outcome of this lab/activity?

What could the teacher/facilitator have done to improve your learning and/or the outcome of this lab/activity?